Constellation-X and Hot and Cool Stars: Present Science Goals

- Undertake plasma spectroscopy and Doppler imaging of coronal activity in both late and early type stars to directly determine the temperature distribution, the location, the volume and the density of the emission regions.

- Study magnetic reconnection, mass motion, densities, and abundances in stellar flares.

- Investigate the solar-stellar coronal connection by obtaining high resolution spectra of stellar coronae over a range of luminosity that includes nearby late-type stars with luminosities comparable to the sun and the brightest stars in globular clusters and the Magellanic Clouds.

- Investigate the formation and evolution of magnetic dynamos in young and pre-main sequence stars buried deep in molecular clouds by observing their X-ray coronal activity at high spectral resolution

Constellation-X and Hot and Cool Stars: Science Drivers

ϖ For stars, effective area is the primary improvement compared to previous missions.

- At energies < 5 keV, Con-X will be able to get high-resolution spectra of `normal' stars and low-luminosity objects such as planets, comets and brown dwarfs (most of which have soft and faint X-ray spectra): almost all stars observed by Chandra and XMM-Newton gratings are exceptionally active.

- At energies > 5 keV: Astro-E2's 150 cm^2 at Fe K is only going to be enough to do a handful of stars well, e.g. Eta Car, Algol, etc., and mostly active coronal binaries. Con-X's 6000 cm^2 will open up other classes of objects: protostars, luminous stars in LMC and SMC, nearby dwarf stars, etc.

- Spectral resolution: many stars have phenomena with characteristic speeds of ~ 100 - 300 km/s, e.g., binary star velocities, jet velocities => need resolution of 1000 - 3000.

Constellation-X and Hot and Cool Stars: Science Drivers

- Hard X-ray capability: most non-degenerate stars emit very weakly above 10 keV, and few detections >20 keV. Where are the nonthermal X-rays?

- The effective area of Con-X is such that it can provide good temporal resolution (~kiloseconds) of moderately bright flares. This will mean that we will be able to look for transient Doppler shifted or turbulent broadened plasma components with velocities ~ 300 km/s and power-law emission during the rise phase of such flares (both of which are in fact seen in solar flares). The XMM-Newton and Chandra gratings are not likely to accomplish this, Astro-E2 may if it can catch a big flare such as the 1997 Aug 30 flare caught by BeppoSAX.

Line Profiles In the O star Delta Orionis (Miller et al. 2002): Why So Narrow?

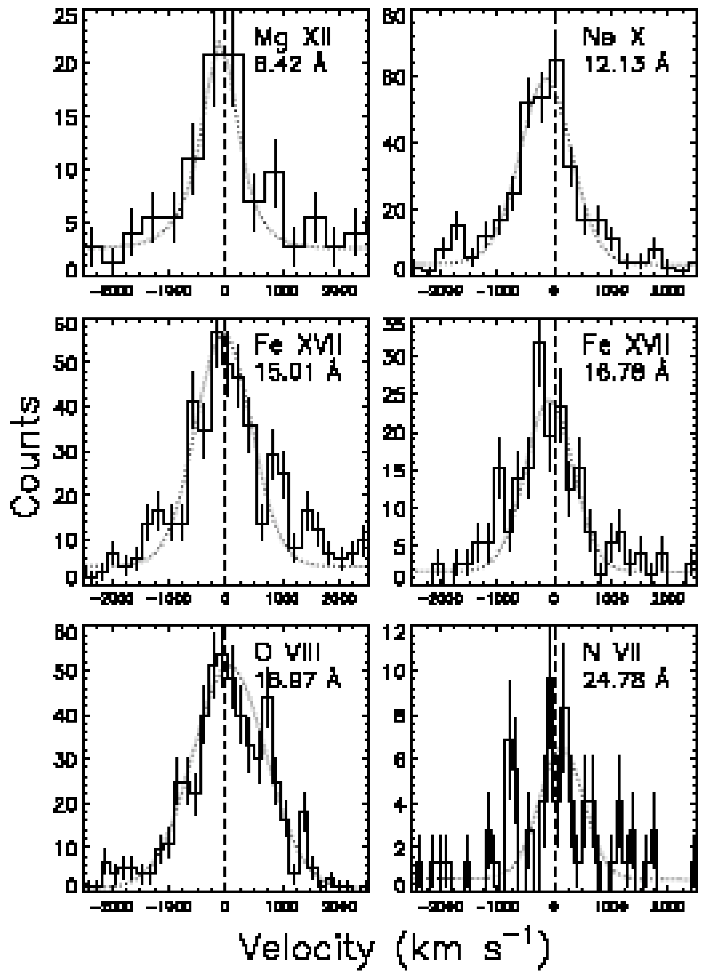

FIG. 3.—MEG co-added first-order X-ray line profiles (*solid*) and Gaussian fits (*dotted*) for six of the brightest lines in the δ Ori spectrum. The vertical dashed lines indicate the rest wavelength for these transitions, and Poisson errors are indicated by error bars. The lines are mostly symmetrical about line center, and all show Doppler broadening. The bin size is 0.01 Å. Parameters for these line fits are given in Table 2.

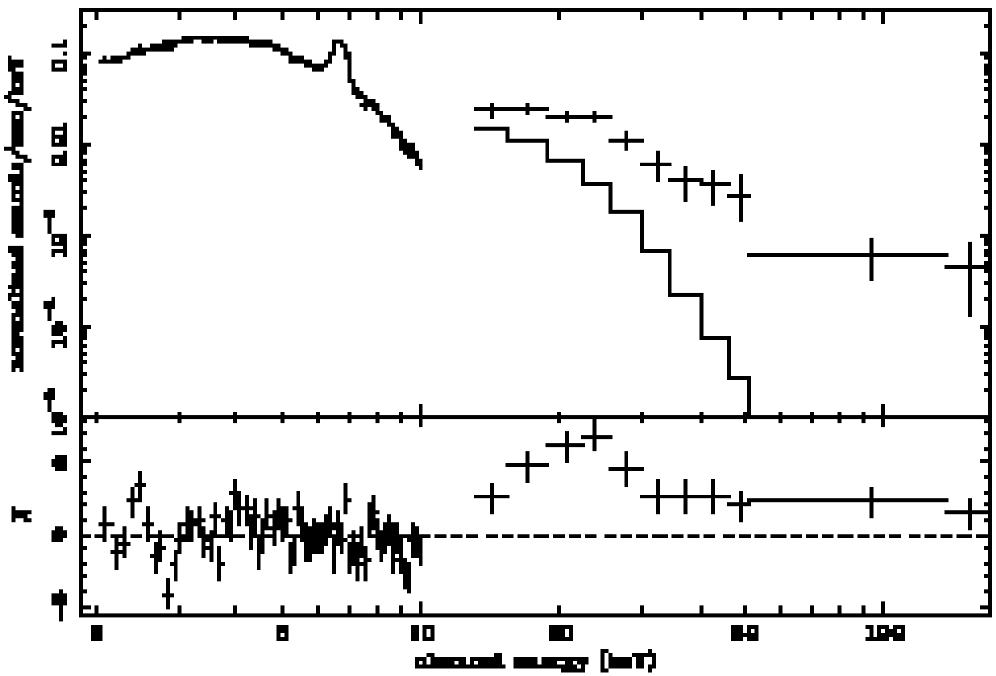

Fig. 3. Upper panel: Results of the fit of the June 2000 BeppoSAX MECS background subtracted spectrum with a one temperature (5.51 keV) MEKAL model. The spectral model is extrapolated to the PDS energy range in order to show the high energy flux excess. The residuals are plotted in the lower panel.

100 ksec BeppoSAX observation of Eta Carinae (Viotti et al. 2003)

Some flare issues that Con-X could address

- Coronal abundances can be studied as a function of time during the various flare stages (impulsive rise, flare maximum, early decay, late decay, etc.) for species such as Si, S, Ar, Ca and Fe (and during non-flare times with lower temporal resolution).

- Turbulence and bulk motion of flare plasmas can be studied, giving information on part of the flare energy budget as yet known only for solar flares.

- Emission from photoionized neutral and singly-ionized Fe in the photospheric and chromospheric layers (Fe K-alpha at 6.40 keV) can be searched for: this can be used to constrain the flare location above the stellar surface if the photospheric Fe abundance is known.

- Hard X-ray (non-thermal) emission from the impulsive phase of stellar flares could be detected, and compared to solar flares.

- The ultimate goal will be to determine whether stellar flares are basically similar to scaled-up solar flares or if they can be inherently different

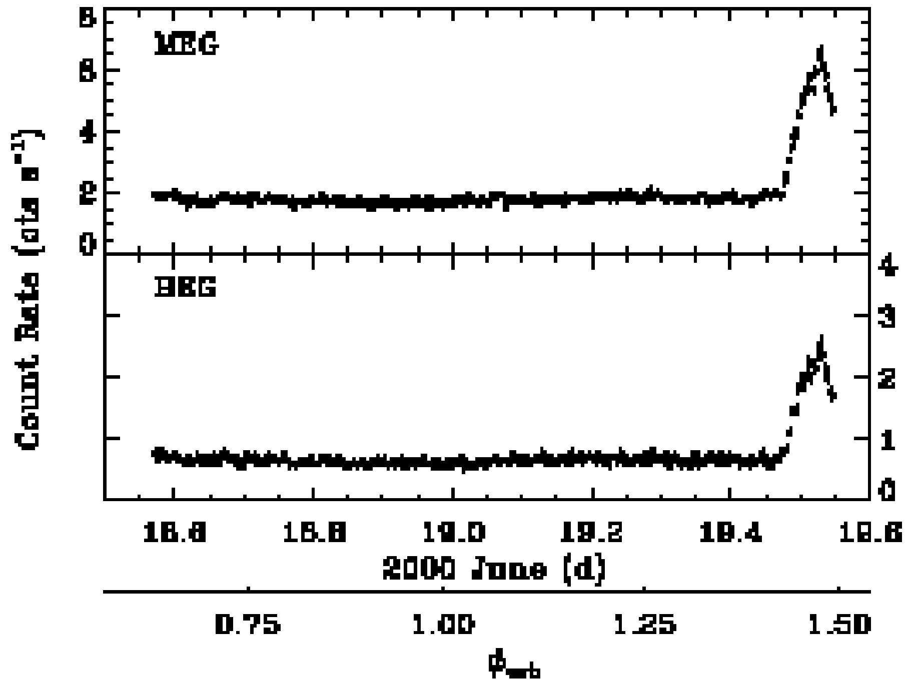

FIG. 4.—*Chandra* energy integrated (0.3–10 keV) light curves (*top*: MEG; *bottom*: HEG). Each bin represents 300 s of data; the error bars are 1 σ. The rise and initial decay of a large flare are seen in both MEG and HEG at the end of the observation. Binary orbital period coverage is indicated at the bottom.

Sigma^2 CrB Flare seen by Chandra (Osten et al., 2003)

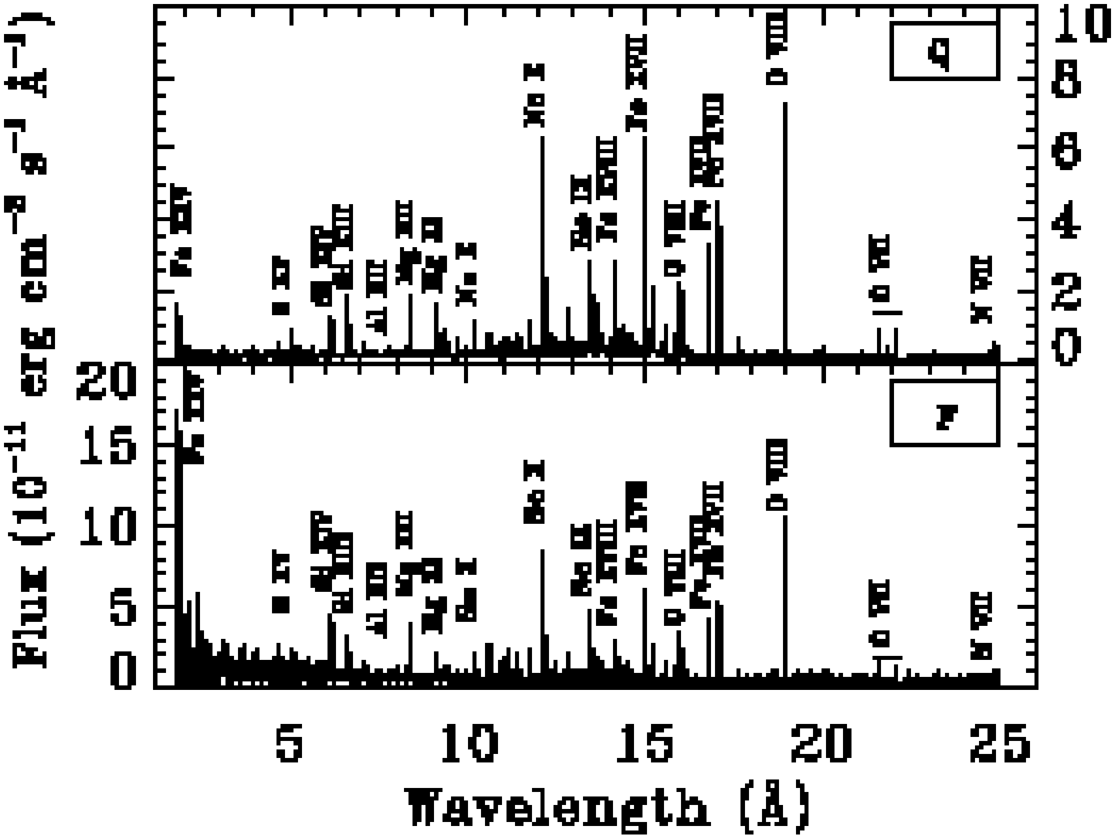

FIG. 7.—*Top*: MEG spectrum obtained during quiescence. *Bottom*: MEG flare spectrum. Selected bright lines are identified. Note the difference in flux scales between the two spectra. The increase of flux toward shorter wavelengths in the flare represents enhanced continuum emission.

MEG Spectra of Quiescent Emission and **Entire** Flare (Osten et al.)

Changes to Con-X Baseline Specs to Enhance Stellar Observations

- Spectral Resolution in Fe L region increased to 1000–3000 to better match typical velocities of interest

- Angular resolution improved to 5" to lessen confusion and enable optical, IR, or radio counterpart in SFR's, clusters and nearby galaxies

- Increased FOV size to enhance ability to multiplex in crowded regions: >=5' .